SUPERVISOR'S USE ONLY

S

93101A

931011

Draw a cross through the box (☒) if you have NOT written in this booklet

+

OUTSTANDING SCHOLARSHIP EXEMPLAR

Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Scholarship 2023
Biology

Time allowed: Three hours
Total score: 24

ANSWER BOOKLET

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

Write your answers in this booklet.

Start your answer to each question on a new page. Carefully number each question.

Check that this booklet has pages 2–27 in the correct order. Pages 2–4 are blank and are to be used for planning. Pages 5–27 are lined pages for writing your answers.

Do not write in any cross-hatched area ( ). This area may be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

PLANNING

• factors:

- territorial with large territories, leading to decreased chance of finding mate. = low repro rate
- reliant on food source = rabbits. specialists dependence = bad, decline in rabbit numbers = decline lynx
- K strategist, few young requiring lots of care = altricial young.
- ~~population bottleneck~~
- hunting + human intervention. Link to kill mother low chance offspring survive.
- bacteria = decreased fitness, less repro + survival.

• intervention

- captive breeding
  but inbreeding as population bottleneck.
- freezing of embryoes
  use future if low numbers, restore diversity + add alleles back in. ~~A~~ future
- all the things to lower death rates.

PLANNING

- circumstances
  - biological species concept requires reproductive isolation such that members from the two groups are unable to reproduce to bring about fertile offspring. [How? same 2n number probs.]
  - issue = in some cases, supposed different species ~~can~~ CAN achieve this.
  - at the same time, the two are not really the same species, as they are adapted to fulfill different niches & do not arise from a particularly recent ancestral population.

- alternative evidence
  - genetic analysis required. -
  - Need to identify some sequence unique to each original population, ~~and~~ look for it in birds wanting to be distinguished. Will also prove hybridisation if both present.
  - may require extracting DNA from perished individuals - mostly pāteke, as low # numbers.

- impact decisions
  - because able to interbreed successfully, hybrids formed regularly, and are difficult to distinguish from the parent species.
  - hence difficult to ascertain if hybrid or pure.
  - hence difficult to know which could be killed + just unrealistic as no way to know really.
  - could try restoring pāteke original habitats
  - long range flight, need sufficient isolation.

PLANNING

QUESTION ONE:

Many factors have contributed to a decline in population numbers of the Iberian lynx over time. A first comes from their territoriality. The territories are held by only a single individaul and are very large. This has a few effects. First, the nature of these territories means that the frequency that males and females meet will be very low. This means that the reproductive rate is also very low, as one must meet before reproducing. In addition, as the territories remain stable for long periods of time, there is likely to be inbreeding and/or repeated breeding between the same members of the population, who have adjoining territories. This means that there is a limited ability for recombination of alleles and increasing of genetic diversity within the population. The smaller the amount of genetic diversity, the greater the risk to the population if environmental conditions change, as there would be little for natural selection to work with to bring rise to new adaptations, hence population numbers would drop dramatically.

In addition, territories must be defended. This takes a large amount of time and energy, particularly when the territory is so large. This means that the Iberian lynx could easily become exhausted and ultimately invests less time into hunting and mating than it could do. This ultimately reduces the birth rate of the population, hence putting them at risk of a decline in population numbers.

Further to this, the parental care to maturity of females also has an effect. First, although the females mature early, they do not reproduce until they obtain a territory. The local territories are so stable however that this may not occur, for some time. Essentially this means the number of breeding females is reduced below its potential. ~~Agg~~ Again reproductive rates are reduced. In addition to this, the survival rate of the offspring that are produced is low. The Iberian lynx bears altricial (helpless) young, that require large amounts of care, hence they are K-strategists. This means that the parent must invest additional energy in caring for young. This energy could otherwise be used for defending their territory, which if lost, would remove them from the group of breeding females. Expenditure of energy also increases the risk of the parent dying ~~the~~ if they do not acquire enough food to maintain their efforts. This is a huge ~~rep~~ reduction in fitness. If the mother lynx does perish, the chance of any young kits surviving is greatly reduced. ~~a~~ This becomes a problem because the birth rate drops below the death rate, so that there is a net decrease in population numbers during a breeding season. Acting as a catalyst for this is human interference. Our activities have lead to the increased death rates that cause this problem. First, there was a population ~~p~~ bottleneck due to our hunting of this species for sport. ~~A~~ A small number of individuals remained, that would not be genetically representative of the whole original population. Inbreeding, coupled with low reproductive rates to begin with, will have reduced the ability for the lynx population numbers to be restored, as with inbreeding there is a high chance of harmful ~~a~~ recessive conditions being brought out in offspring, meaning these individuals are unlikely to survive and the parents just wasted energy on producing offspring that will not secure the genetic line. This is a great reduction in fitness.

Then, even though the species is now protected, death rates remain high from human structures like roads, cities fragmenting their habitats, and more. This has only ensured that the death rate remains too high for the population to increase in size, and ultimately all of this contributed to bringing the Iberian lynx population to an extreme low, earning it its endangered status.

Human intervention has ~~at~~ least prevented the extinction of the species. A first way this has been achieved has been through conservation efforts that protect the Iberian lynx's habitat. By preventing further human development or activity in certain areas, the lynx can exist in those areas undisturbed, carrying out feeding and breeding practises more effectively. This comes ~~from~~ with a reduced amount of ~~[illegible]~~ human removal (and even increased addition of) ~~of~~ their main food source - ~~rabbits~~ rabbits - such that they are more able to acquire sufficient energy to support both themselves and any offspring produced, such that the fitness of the species can be restored. This ultimately assists ~~the~~ a rise in population numbers that bring the Iberian lynx away from extinction.

Another method has been to use captive breeding programmes. This involves removing adults or recently born offspring from the wild, and raising the offspring under human influence. This has been beneficial as in captivity, the offspring will be guaranteed to have sufficient energy for development to maturation, hence increasing the proportion of offspring per litter that survive compared with in the wild. This means the population numbers can be made to be increased much more rapidly than they would naturally with the low birth & survival rates. This has lead to an increase in population size from 100 individuals to ~1110 in 2021. A larger ~~greater~~ population ~~size~~ is ultimately ~~lower~~ at lower risk of genetic drift caused by random events, which means that the genetic diversity of the group (although already limited by population bottleneck) is more likely to be maintained in the population. This reduces the likelihood that any change in environmental conditions will adversely ~~adversly~~ effect population numbers again in future.

Further to this, Iberian lynx embryos and oocytes have been frozen. This is genetic banking and is a safety measure for future conservation efforts. This is a good thing to do because the genetic information contained in the embryos can be reintroduced to the population if there is a later decline in genetic diversity. This ultimately ensures that genetic diversity will be maintained in the Lynx population. As well as this, these embryos can be used to increase population numbers above what may be possible with the number of available breeding pairs. Potentially, in future, the females selected to carry the offspring could be those that are not yet reproducing as they don't have an established territory. This would then increase the total number of reproducing females and hopefully increase the birth rate of the population.

An issue that will have to be mitigated is that of genetic disorders. Firstly, the conservationists involved would have to avoid inbreeding. They may have to use genetic sequencing to determine ~~the~~ how similar ~~two~~ individuals are before using them as breeding partners.
Another issue that needs to be addressed is that of the bacteria living in the wild lynxs' digestive tracts. There may be a way in which scientists could edit the genome of either:

- the lynx, to give it some kind of natural tolerance or adaptation to kill the bacteria, such that contracting it does not decrease fitness. (This will rise through population as beneficial!)
- the bacteria, such that there will be a spread of genetic information in the bacteria population that will ultimately prevent it from prospering / surviving, hence eventually eradicating it. This would again remove the ~~po~~ problem of the lynx's decreased fitness.

So there are many things that have contributed to the past decline in lynx numbers, both natural & due to human influence, but restoration is possible, ~~and~~ with the ultimate target being ~~a~~ ~~achievement~~ ~~of the~~ a state of conservation that is favourable.

QUESTION TWO:

The interspecific relationship of herbivory is a type of exploitative relationship, where the grazer is advantaged in gaining a food source for relatively little energy cost/effort, while the plant is disadvantaged due to the damage of its tissues and removal of structures that take energy to reproduce. This is the relationship between the Moa & the horoeka. Herbivore & plants then act as a kind of selection pressure on each other, and co-evolution occurs. This is certainly observed in the horoeka. This plant ~~made~~ has developed adaptations that decrease the frequency of the moa grazing on it, thus effectively removing the disadvantage described above.

A first adaptation that has resulted in the horoeka saplings is that of defensive colorisation. The moa will have initially been grazing on those saplings that it could easily see and identify as a source of food. This means these individuals were hence more likely to be killed and their ability to contribute their colour genes to the next generation was limited. A genetic mutation must have given rise to the brown colour type, which was then effectively selected for by the moa, as this type could not ~~then~~ be seen and identified as a food source. These individuals then passed on the allele for the brown colouring to future generations at a greater rate, and this allele will have risen in frequency until it became fixed in the population.

A second adaptation that has arisen in the horoeka is that of armament, with spines formed on the juvenile leaves. These spikes would ultimately harm the moa as it consumed them, leading to the deterrent of the moa from eating the plants exhibiting spikes. This, as with defensive colourisation, then increased in frequency in the lancewood population. In conjunction with this, the juvenile leaves display green spots close to the end of the spikes. As it is reported that this colour is highly conspicuous to birds, it is possible that that is due to a type of mimicry. There may be another species of plant with that colouring, which is unpalatable to the herbivorous birds like the moa. When the horoeka also displays this colour, in batesian mimicry, the grazing birds do not approach it as they associate the colour with the unpalatable species and assume the horoeka is the same one. As this trait reduces the frequency of grazing by herbivores, it allows saplings to reach maturity and contribute the alleles to the future generations, giving rise to this adaptation over time.

As well as this the shape and orientation of the leaves has changed. ~~they~~ In juvenile forms they are long and blade like, pointing down towards the ground. This deters moa due to their grazing style. The moa approach the plant and consume the leaf as a whole. When the horoeka leaves are long and pointed downwards, the moa are more likely to experience discomfort when trying to consume the leaves, as they would stick down into the backs of their throats. This would then deter the moa from returning to the plant to graze on the leaves, as they know that it is a rather inconvenient and unpleasant experience. Again, as ~~they~~ the individuals with this leaf pattern survive to adulthood, the moa has selected for them and they have risen in frequency.

The horoeka displays drastically different features upon reaching maturity. At this time in their life cycle, they have reached a height of ~3 metres tall. After this, they lose the adaptation that deter the moa. This is because the moa generally could not grow to that height, certainly with variation among the different moa species. No moa was ever going to surpass more than 3 meters in height. This means that after a certain time the moa could no longer reach the leaves of the lancewood to graze on them, as leaves will be produced at the top of the tree where they have the best access to sunlight. This meant that, the adaptations to prevent herbivory of land-grazers ultimately became 'useless' after reaching this age. There was no selection pressure to ensure the features were retained through to adulthood, and in fact, it would have been more beneficial to the lancewood to invest energy in generalised 'normal' plant structures and growth at this stage as this is what would allow them to obtain the nutrients they needed for survival. seen So it is because the moa could no longer consume ~~adult~~ adult lancewood material as a ground-dweller, that the heteroblasty was able to come to be.

seen

Eg. green leaves with greater surface area with which to photosynthesis at a maximum rate to produce sufficient glucose to support the plant and its future growth.

Despite the fact that the moa (all species) are now extinct, the lancewood still displays its heteroblastic adaptations. A first reason for this will be that the moa has only gone extinct relatively recently in evolutionary terms. This means that there has been insufficient time for any new selection pressures to change the traits in highest frequency within the lancewood population. Hence it is currently retain its heteroblastic traits despite the removal of its main herbivore.

Further to this, the adaptations have not become unfavourable. Firstly, there is no real selection pressure to dictate for a reversion to a non-heteroblastic form, as the heteroblastic form does still survive to maturity and passes on its genetic information to the next generation. This means there is not much driving a change in general.

As well as this, the adaptations will still prevent herbivory from other herbivores. These days those include the introduced cattle, sheep and deer, as well as the takahē, ~~and~~ kōkako and kererū. All of these herbivores grow to heights under 3 metres tall, just as the moa did, and therefore will graze on shorter and juvenile plants. This means that even since the extinction of the moa, the heteroblastic adaptation still provides the lancewood with some advantage, as the juvenile forms still will not be consumed as readily, such that they survive to adulthood. Essentially this has just meant that the adaptation ~~~~ has been retained by the lancewood population.

It is therefore very clear that the moa, in particular acted as a significant selection pressure for ancient lancewood populations, particularly as ~~those~~ the Chatham Island species, which was not subjected to such extensive herbivory, displays none of the heteroblastic adaptations. Both species will retain their ~~the~~ traits until there is a change in the selection pressures acting on them.

QUESTION THREE:

The biological species concept requires groups to have an inability to reproduce to create fertile offspring (ie. are reproductively isolated) before they can be considered different species. The pāteke and mallard ducks have been labelled as two different species. This does seem to be correct as the two have arisen in completely different parts of the world, and ~~have~~ were hence geographically separated for a long period of time over which they each evolved, with pāteke endemic (only found in) New Zealand. This means the two would not share a particularly recent common ancestor. It also means they have adapted to fulfill slightly different niches, with the Mallard occupying open grassland and the pāteke occupying wetlands and ~~other~~ densely shrubbed areas. It is thus very difficult to think that the two should be considered the same species.

However they are an active contradiction of the biological species concept, as members of the two groups can indeed ~~not~~ interbreed to produce fertile offspring (hybrids). The concept would then define them as the same species, but indeed it does not seem that they are so. This contradiction is observed elsewhere in the world, through the existence of 'Ligers' for example. These are ~~only~~ hybrids born to Lion & Tiger parents, and have been considered fertile. In this case they are only produced on rare occasions where Lion and Tiger distributions overlap. But certainly, species exist that do not fulfill the biological species concept. This ultimately puts the concept in question and means that it is probably insufficient for distinguishing species. ~~as different~~

The two duck species evidently share some similarities (perhaps same 2n number) that allow them to succesfully hybridize. Unfortunately, the three (mallard, pārera, hybrid) can be difficult to distinguish from each other. One method that could be used to distinguish this is DNA sequencing. DNA of individuals suspected to belong to the two different species should be sequenced. Upon ~~a~~ achieving this, differences will be able to be identified in the two genomes. It is these differences that will allow them to be distinguished. This would be most effective if a sequence that is unique to each species is found. This could then be used as a kind of 'flag' tool, as if an individual carries it they must be related to ~~that~~ that species. In the case of hybrids, they could be distinguished easily if they carried a mosaic of genetic sequences ~~fro~~ from each of the two ancestral groups.

Further to this, mitochondrial DNA (mtDNA) may become useful. mtDNA is not effected by meiosis as it exists outside of the cell nucleus. This means that it does not undergo recombination events as with chromosomal DNA. This means that changes in mtDNA can only be brought about by mutations. It has been found that these mutations occur at a ~~std~~ steady, regular rate, and hence mtDNA is used as a molecular clock. The more similar the ~~DNA~~ mtDNA, the more closely related the individuals / more recently they shared a common ancestor. This could be a very useful method by which to prove that the mallard and pārera should be different species. It is likely that their mtDNA will be different, due to the large amount of time over which the two were isolated. This ~~can~~ ~~be~~ be used to suggest they are different species and also used to distinguish ivory birds, as mtDNA will show its genetic lineage to either or both species.

The ability of the pāvera and mallard to successfully hybridise brings about issues regarding the ability to conserve each as a separate species.
First of all, because the hybrids look very similar to either ancestral species, they ~~are~~ are difficult to identify, particularly from long distances. This is most relevant to ~~the~~ duck-shooting, as hunters will not be able to distinguish the birds. This makes it effectively impossible to impose a ban on hunting pāvera, as they will ultimately be killed by mistake regardless. Further to this, duck-shooting is actually a necessary activity in New Zealand in order to prevent duck ~~popu~~ populations (particularly mallards) from becoming too large. If this occurred they would likely begin to outcompete other endemic species for resources, or damage plant species that they may consume and/or live among. This ultimately poses a greater threat to New Zealand's biodiversity than ~~the~~ extinction through hybridisation that the two ducks (mostly pāvera) are facing.

The extensiveness of the hybridisation events have also had an influence. The mallard ducks were introduced a long time ago (20th century) and in large numbers ~30,000. This ~~at~~ means there has been a large amount of time over which hybridisation has occurred and are now concerned that very few pure pārera individuals exist. The reason that this is a problem is that there is not a large amount of sense to actively attempting to conserve a species that may or may not exist, particularly when other, very much identifiable, endemic New Zealand species are at high risk of extinction. It is thus unwise to invest in the ducks over others.

To add insult to injury, the likelihood that a population of pure pārera could be successfully set up and isolated from mallards is low. First of ~~all~~ all, numbers of pure pārera are thought to be extremely low. This would necessitate inbreeding to increase population numbers. This is a problem because it is highly likely for autosomal recessive genetic disorders to arise in offspring, and ultimately the population would have very little genetic variation and would remain unstable. So ~~even~~ restoring the pārera population at all seems far fetched.

As well as this the pārera population would have to remain isolated from any mallard or hybrid individuals, otherwise gene flow would occur and hybrids would be reproduced, jeopardising the effort to restore a pure pārera population. The problem is both mallard and pārera can fly very long distances (~1500km). This means that the islands ordinarily turned to for conservation efforts (like Tiritiri Matangi, Great Barrier etc.) are not sufficiently far from the mainland to ensure geographic isolation and prevent gene flow. Far off islands like the Chathams would have to be used, and ultimately this would require a large

investment of resources to ~~be achi~~ succeeful.
Finally, even if a pāvera population was restored, it could never be returned to the mainland, as is usually the goal with conservation efforts. This is because return to the mainland would only lead to hybridisation occurring once again, and all of the hard work being undone. The mallard will never be removed from New Zealand as it is too widely spread, and hence it will never be possible to truly restore pāvera to the mainland.
Effectively, all of this makes conservation efforts somewhat pointless, as the investment of time and money would never be rewarded with the desired results. This ultimately due to the hybridisation ability of the Mallard and pārera. When other species are taken into account, those that are endangered and are standalone species that will not hybridise in the same way, it seems ~~~~ much more important to focus our conservation efforts on the populations, which do have the potential to bring about the desired results. This exactly the decision that has been made. The pārera and mallard are both legally allowed to be shot during hunting season and efforts are not being made to ~~~~ set up and manage pure populations. We have accepted extinction by hybridisation.

93101A

Outstanding Scholarship

Subject: Biology

Standard: 93101

Total score: 20

Q	Score	Marker commentary
1	07	Factors that have led to the decline of the lynx (slow reproductive rate, K-reproductive strategy and bottleneck effect) were clearly discussed with links made to the effect of human hunting on population decline. Justification of the consequence of inbreeding and also the slow rate of population increase were communicated in a concise way. An understanding of the importance of captive breeding programs on the survival of kits, along with increasing the genetic diversity in the population, was evident. This candidate did not receive 8 points as they did not provide full justification when evaluating the current interventions being undertaken to avoid extinction of the lynx species. This candidate gained 7 justification points and 3 evidence points.
2	06	Analysis of the heteroblastic features present in horoeka at each stage of life were analysed with respect to their adaptive advantage to avoid moa herbivory. The persistence of these adaptations, even though the moa is extinct, was linked to the selection pressures exerted by newly introduced mammalian herbivores. Justification of moa being the primary selection pressure leading to heteroblasty in lancewood / horoeka was made by comparing Chatham Island lancewood phenotypes and evolutionary history. This candidate gained 5 justification points and 4 evidence points but did not provide enough in-depth evaluation of evolutionary concepts to fully evaluate other reasons as to why heteroblasty persists today in lancewood / horoeka., to gain full points.
3	07	An example of a limitation to the species concept was used to illustrate the difficulty in clearly defining the point of speciation between species; in this case, ducks. A comprehensive understanding of the usefulness of genetic analysis to ascertain species classification when phenotypes and behaviours are inconclusive was discussed. The candidate provided critical analysis of and reflection on the issues arising from hybridisation of the mallard and pārera related to hunting, identification of phenotypes, hybridisation

Q	Score	Marker commentary
		involving hybrid vigour, and lack of pure pārera to begin preservation from. This candidate gained 7 justification points and 2 evidence points but needed more depth in terms of other limitations to the species concept to gain 8 for this question.